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Analysis of electric vehicle interconnection with commercial building microgrids

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http://eetd.lbl.gov/EA/EMP/emp-pubs.html

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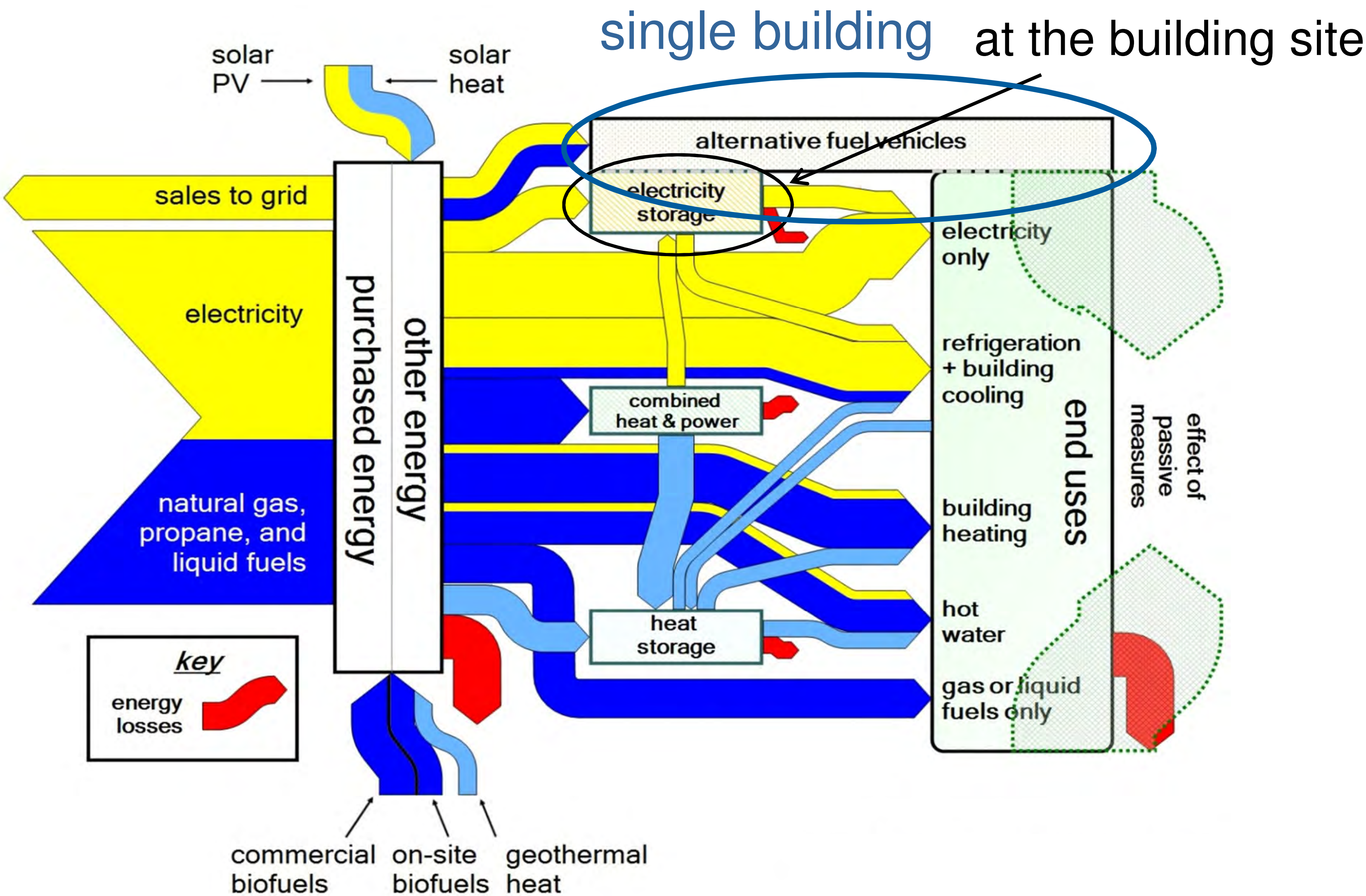
Outline

- global concept of microgrid and electric vehicle (EV) modeling
- Lawrence Berkeley National Laboratory's Distributed Energy Resources Customer Adoption Model (DER-CAM)
- presentation summary

How does the number of EVs connected to the building change with different optimization goals (cost versus CO_2) ?

- ongoing EV modeling for California: the California commercial end-use survey (CEUS) database, *objective: 138 different typical building - EV connections and benefits*
- detailed analysis for healthcare facility: optimal EV connection at a healthcare facility in southern California
- conclusions

Global concept



The Distributed Energy Resources Customer Adoption Model (DER-CAM)

DER-CAM

- is a deterministic Mixed Integer Linear Program (MILP), written in the General Algebraic Modeling System (GAMS®)
- minimizes annual energy costs, CO_2 emissions, or multiple objectives of providing services to a building microgrid
- produces technology neutral pure optimal results, delivers investment decision and operational schedule
- has been designed for more than 9 years by Berkeley Lab and collaborations in the US, Germany, Spain, Portugal, Belgium, Japan, and Australia
- first commercialization and real-time optimization steps, e.g. Storage & PV Viability Optimization Web-Service (SVOW), *http://der.lbl.gov/microgrids-lbnl/current-project-storage-viability-website*

Presentation summary

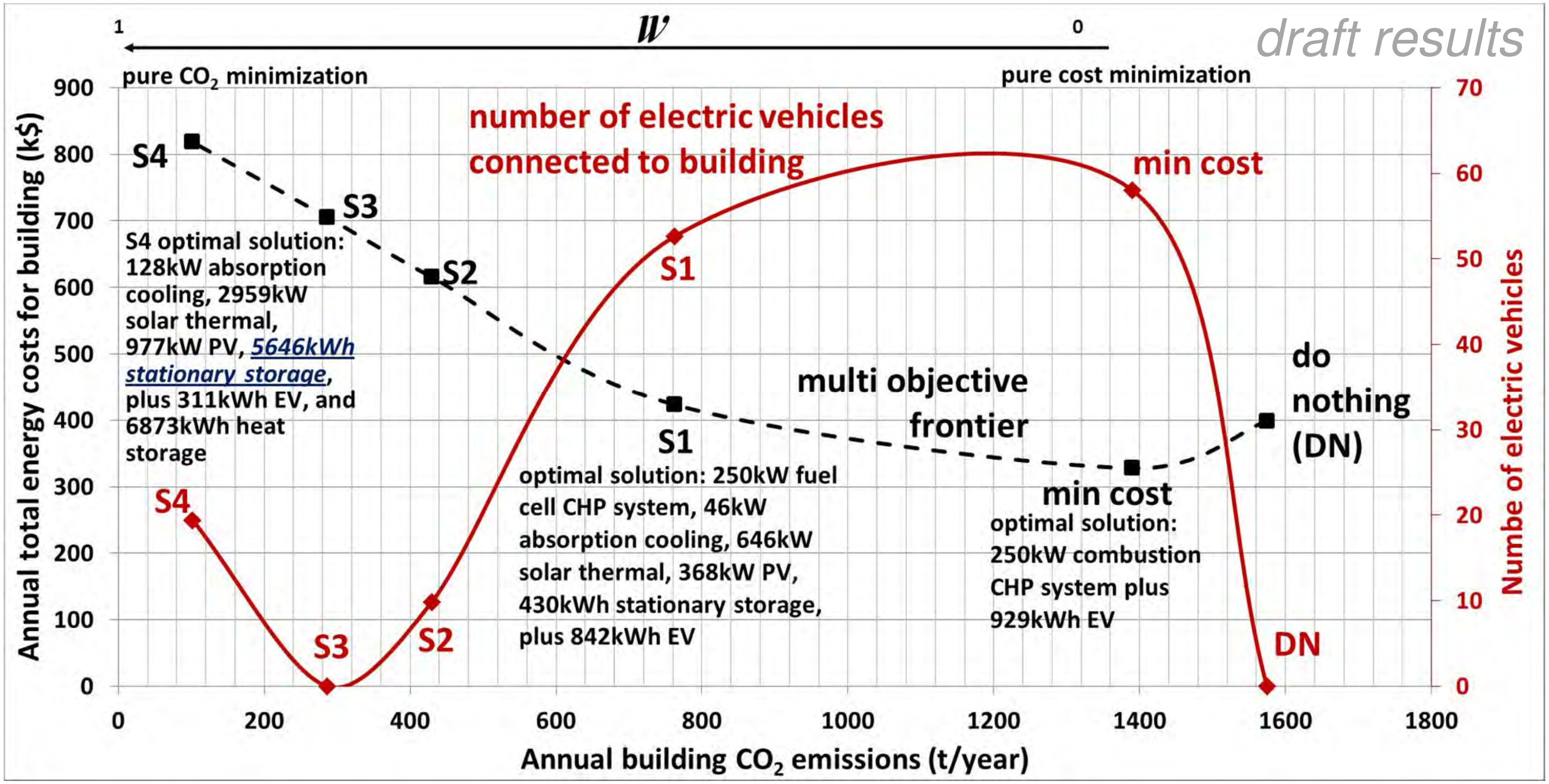
Major Optimization Results for a Healthcare Facility in San Diego Gas and Electric Service Territory

Different optimization goals

Multi-objective frontier (minimize the combination of costs and CO_2 emissions for building)

$$\min\left((1-\omega)\cdot\frac{Cost}{ReferenceCost}+\omega\cdot\frac{CO_2emissons}{ReferenceCO_2emissons}\right)$$

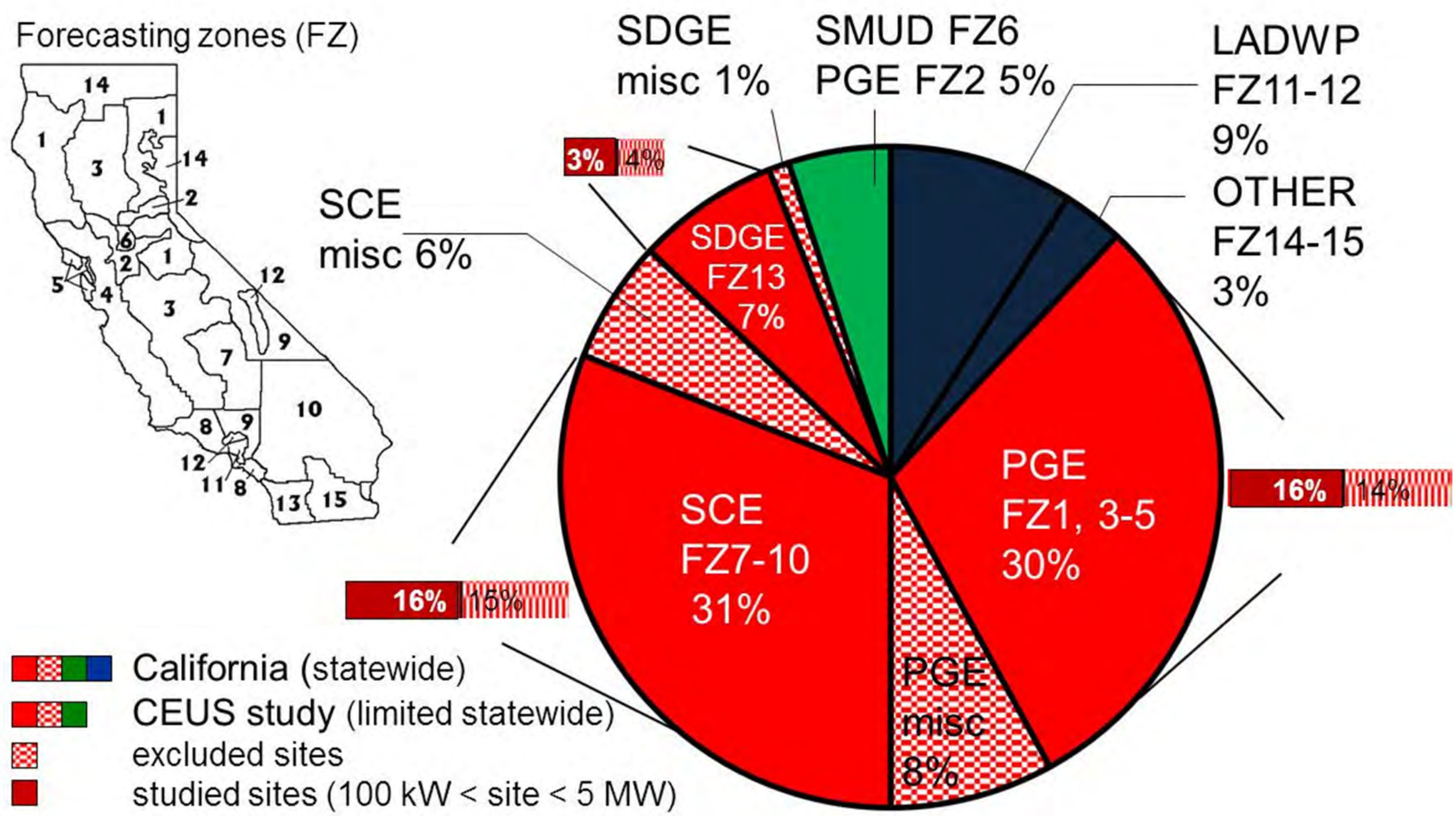
Multi-objective frontier / EVs connected



- ✓ connected EVs reach maximum around “min cost” solution (*w*=0)
- ✓ with increasing *w*: stationary batteries become more attractive to building than EVs → second life of EV batteries?

The California Commercial End-Use Survey (CEUS) Database

CEUS



<u>objective / final EV project goal</u> : EV modeling at 138 buildings[x)] in nine climate zones

x) hospitals, colleges, schools, restaurants, warehouses, retail stores, groceries, offices, and hotels

2020 Equipment Options, Tariffs, and Building Analyzed

Equipment

- EVs belong to employees/commuters
- EVs can transfer energy to the building and vice versa
- the building energy management system (EMS) can manage (charge/discharge) the EV batteries during connection hours
- EV owner receives exact compensation for battery degradation and energy delivered to the building

EV-building connection period	8am – 5pm
EV-home connection period	7pm – 7am
EV battery state-of-charge (SOC) when arriving at the healthcare facility	73%
EV battery SOC when leaving the healthcare facility	≥32%
EV battery charging efficiency	95.4%
EV battery discharging efficiency	95.4%
EV battery capacity	16 kWh
Maximum EV battery charging rate	0.45 [1/h]

Equipment

- also combined heat and power (CHP), PV, solar thermal, stationary battery, etc. is considered in the analysis

- technology costs in 2020 are based on “Assumptions to the Annual U.S. Energy Outlook”, e.g.
  - fuel cell with heat exchanger: \$2220 - \$2770/kW, lifetime: 10 years
  - internal combustion engine with heat exchanger: \$2180 - \$3580/kW, lifetime: 20 years
  - PV: \$3237/kW, lifetime: 20 years
  - stationary battery: \$193/kWh
  - etc.

Details can be found at “The CO_2 Abatement Potential of California’s Mid-Sized Commercial Buildings.” Michael Stadler, Chris Marnay, Gonçalo Cardoso, Tim Lipman, Olivier Mégel, Srirupa Ganguly, Afzal Siddiqui, and Judy Lai, California Energy Commission, Public Interest Energy Research Program, CEC-500-07-043, 500-99-013, LBNL-3024E, December 2009.

Building / tariffs

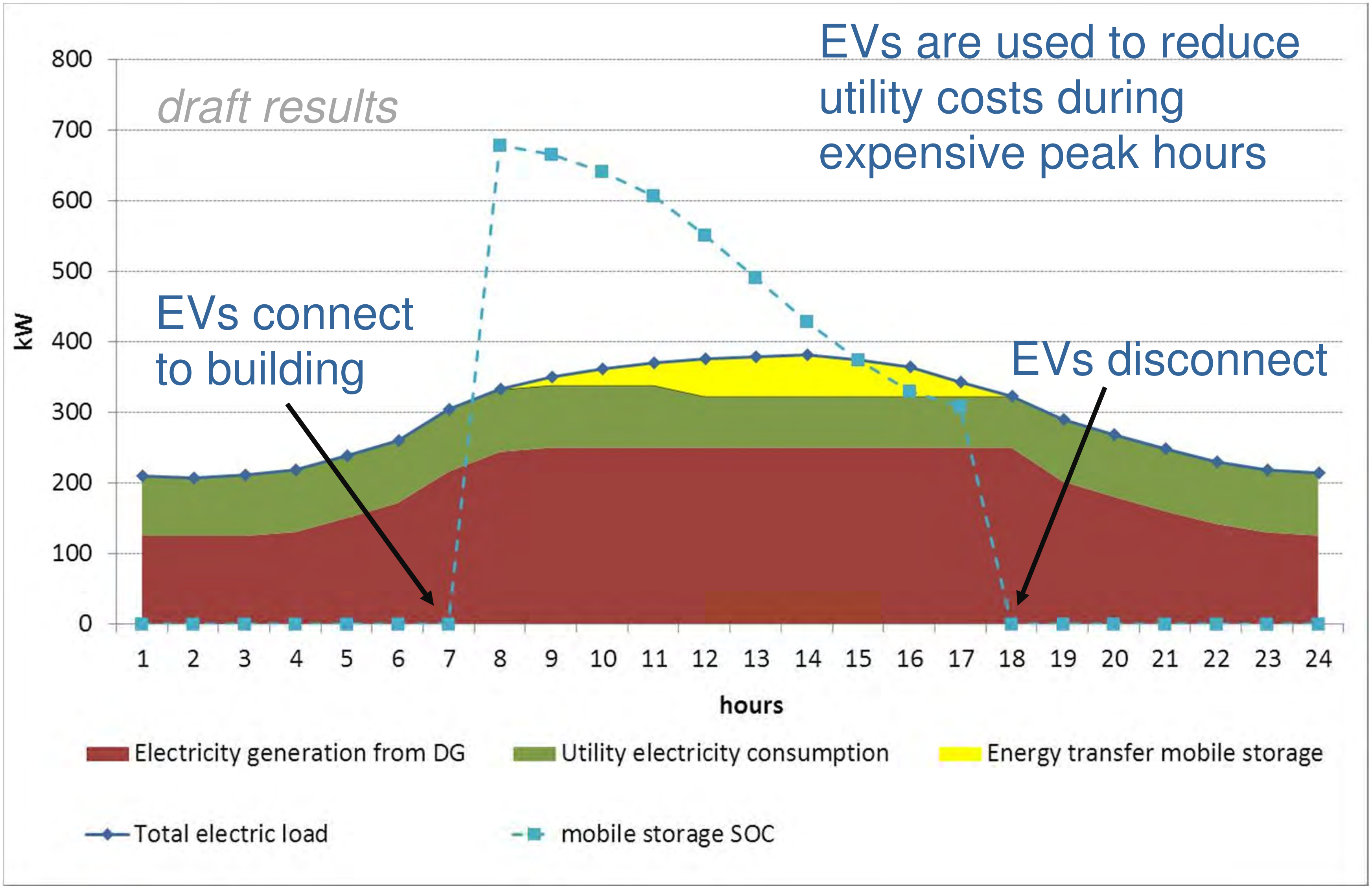
- electricity and gas loads for a San Diego healthcare facility are based on CEUS
  - peak electric demand: 399 kW
  - annual electricity demand: 2.33 GWh
  - annual natural gas consumption: 2.13 GWh (72700 therm)
- TOU rates and demand charges:
  - on-peak electricity up to 0.13 \$/kWh
  - off-peak rates around 0.09 \$/kWh
  - demand charges up to 12.8 \$/kW-month
- electric rate at residences (homes) for EV charging: \$0.138/kWh

Detailed analysis for healthcare fac.

Optimization Results for Summer Days

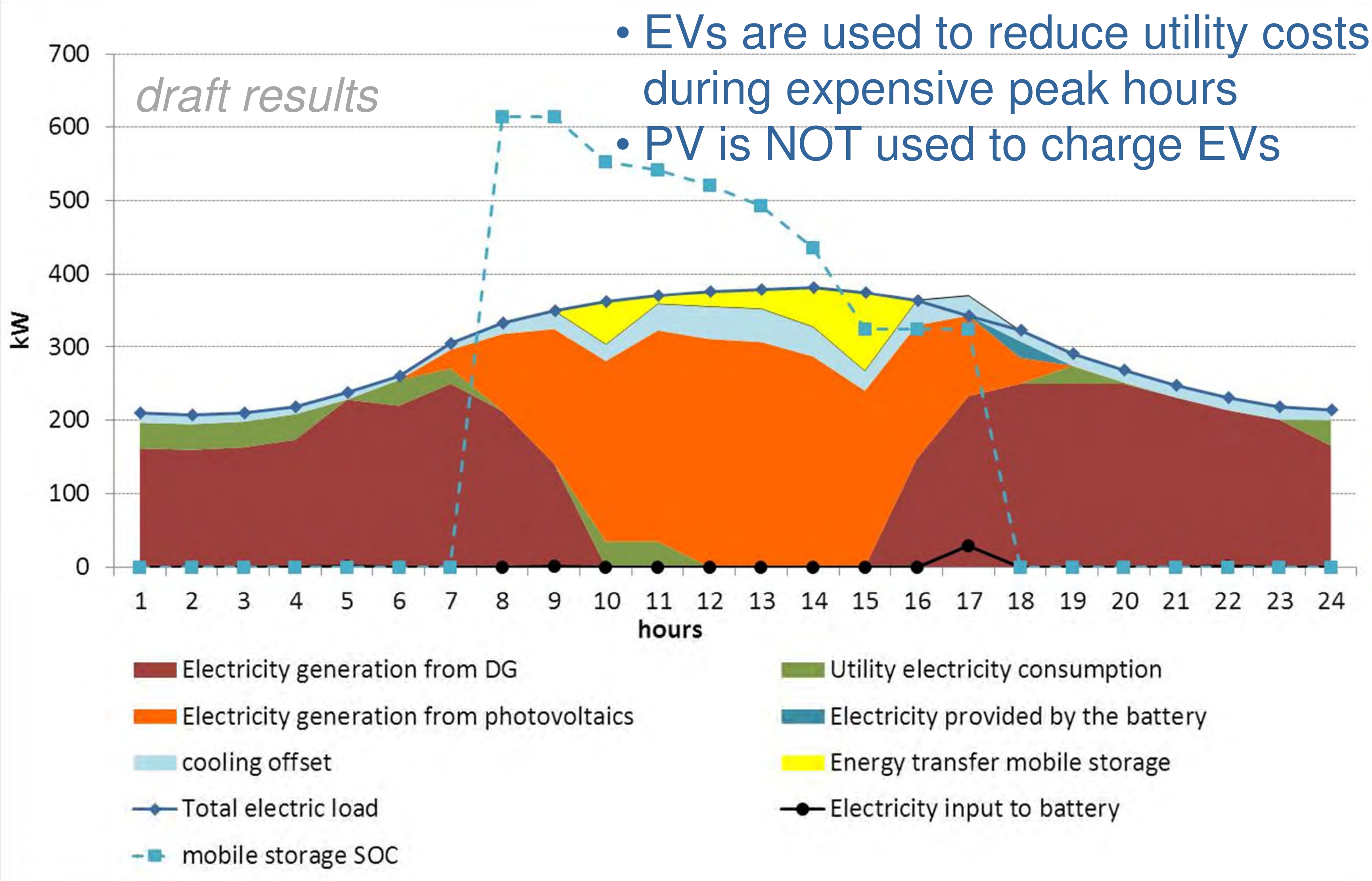
Optimal Investments in DER Technologies and Operation, Optimal EV Discharging / Charging subject to different building strategies

Diurnal electric pattern for min cost

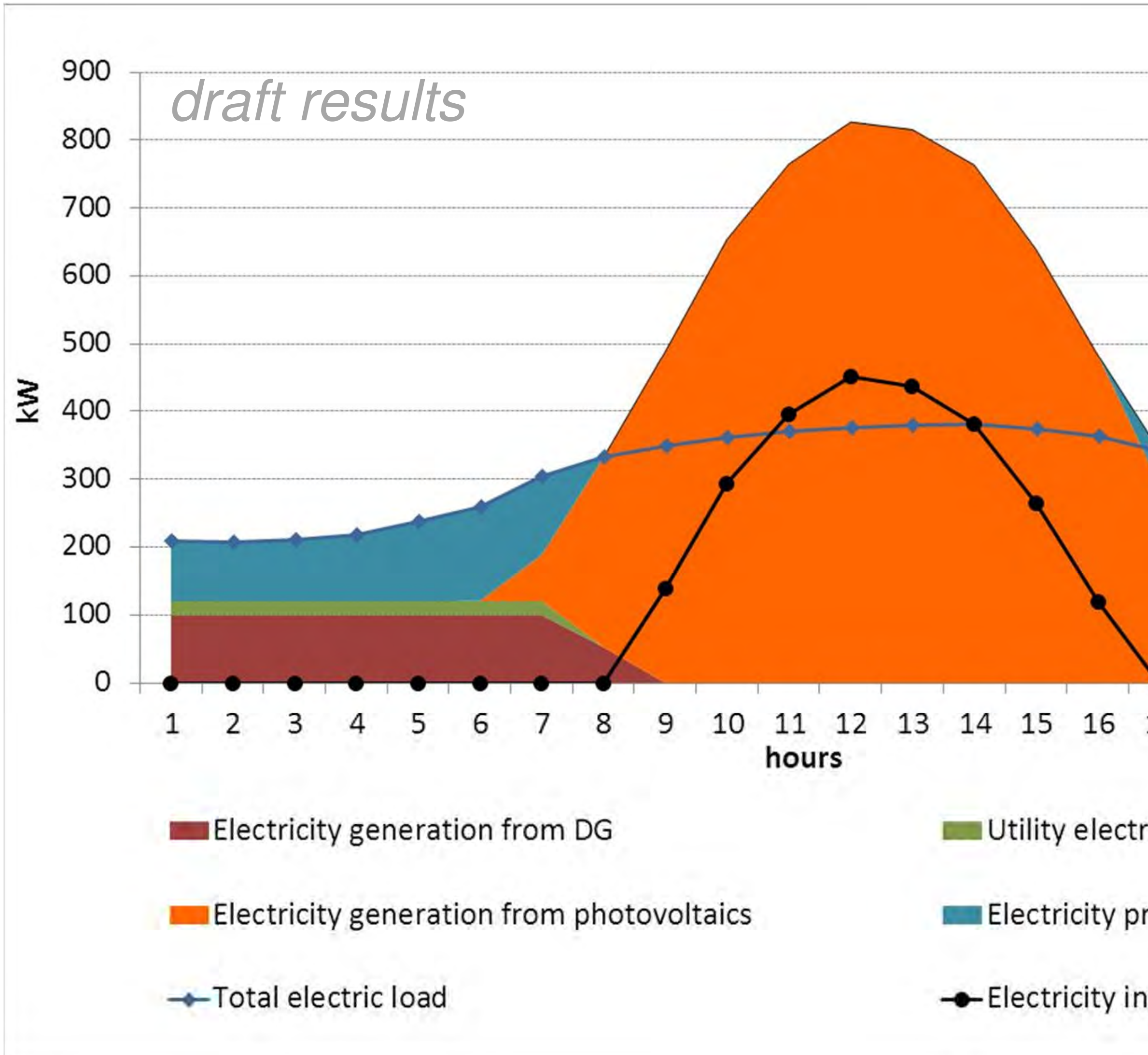


Diurnal electric pattern for point S1

- EVs are used to reduce utility costs during expensive peak hours
- PV is NOT used to charge EVs

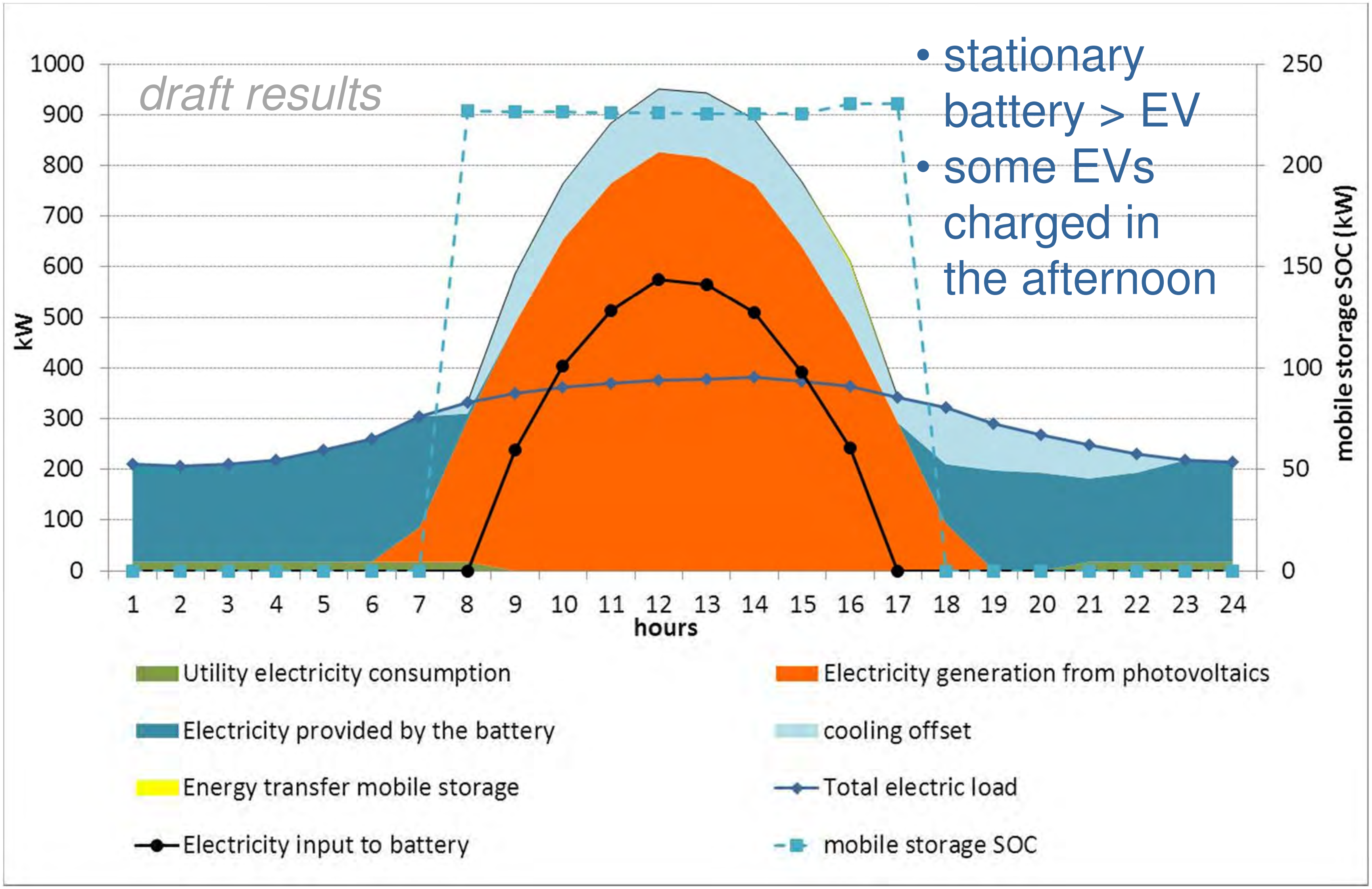


Diurnal electric pattern for point S3



- big stationary battery
- stationary batteries charged by PV
- no EV batteries

Diurnal electric pattern for point S4



- stationary battery > EV
- some EVs charged in the afternoon

Conclusions

Storage conclusions

- EV Charging / discharging pattern mainly depends on the objective of the building (cost versus CO_2)
- performed optimization runs show that stationary batteries are more attractive than mobile storage when putting more focus on CO_2 emissions. Why? Stationary storage is available 24 hours a day for energy management→ more effective
- stationary storage will be charged by PV, mobile only marginally
- results will depend on the considered region and tariff

→ final work will show the results for 138 different buildings in nine different climate zones and three major utility service territories

End

Thank you!

Questions and comments are very welcome.

DER-CAM literature

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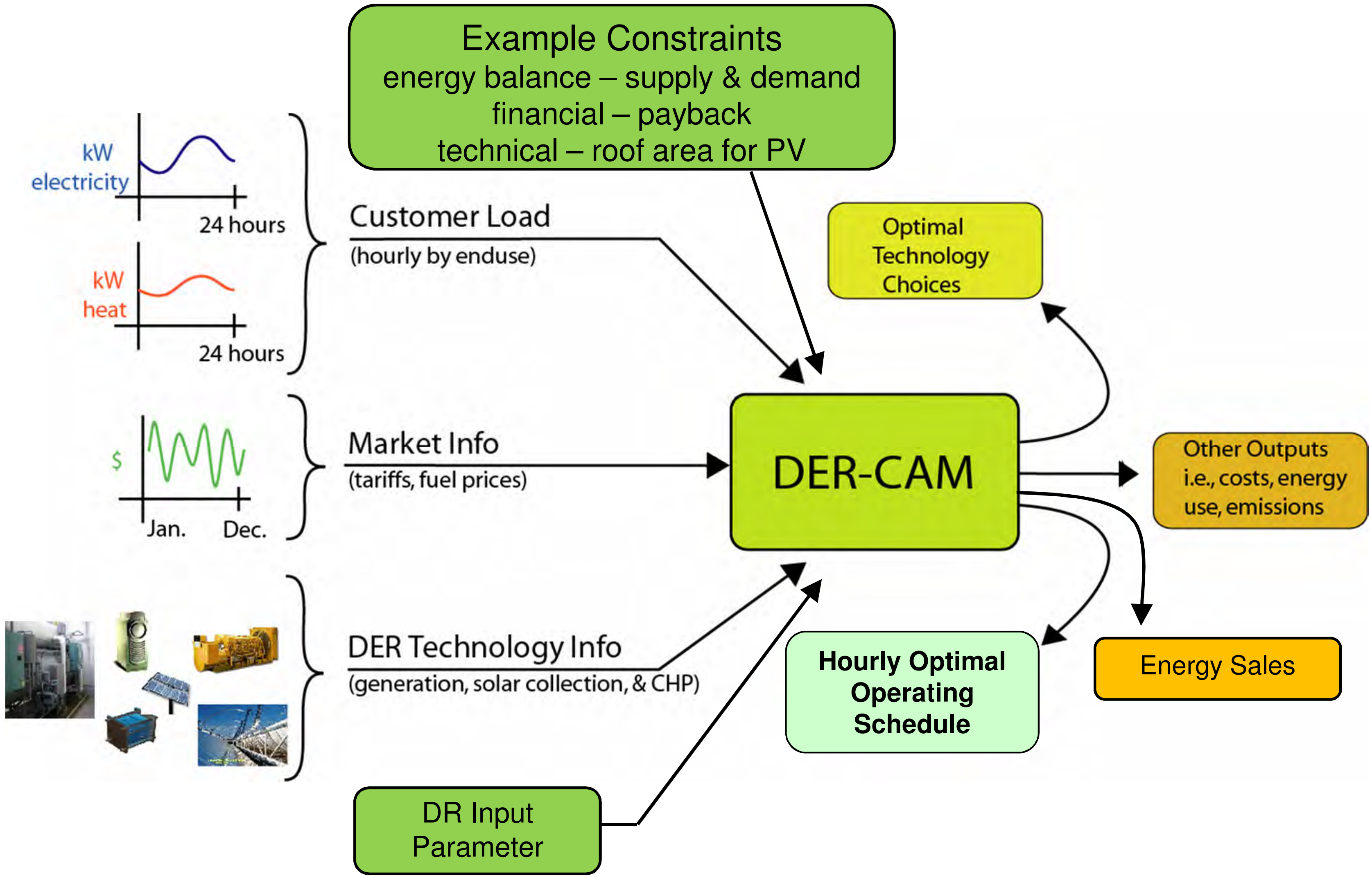
High-level schematic



Representative MILP

Simplified* DER-CAM model

Energy balance
+energy purchase
+energy generated onsite
= onsite demand + energy sales

Operational constraints
-generators, chillers, etc. must operate within performance limits
-heat recovered is limited by generated waste heat
-solar radiation / footprint constraint

Objective function, e.g. min. annual energy bill for a test year:
+energy purchase costs
+*amortized* DER technology capital costs
+annual O&M costs
+ CO_2 costs
- energy sales

Financial constraints
-max. allowed payback period, e.g. 12 years

Regulatory constraints
-minimum efficiency requirement
-emission limits
-CO_2 tax
-CA min. eff. requirement for subsidy and (in future) feed-in tariff
-ZNEB

Storage and DR constraints
-electricity stored is limited by battery size
-heat storage is limited by reservoir size
-max. efficiency potential for heating and electricity

***does not show all constraints**